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(54) **Power control apparatus for use in mobile radio systems**

(57) Rapid feedback control of transmit power for very low bit rate links is difficult because very little signal energy is available for measurement of power. However, the purpose of power control is to maintain a link error rate. By feeding back decisions from the receiving station to the transmitting station, the latter can detect errors at the receiving station. When an error is detected the transmit power is increased. When no error is detected the transmit power is reduced by a smaller amount. This maintains a constant bit error rate related to the ratio of the up and down step sizes.

Fig. 2

TRANSMITTING STATION

RECEIVING STATION
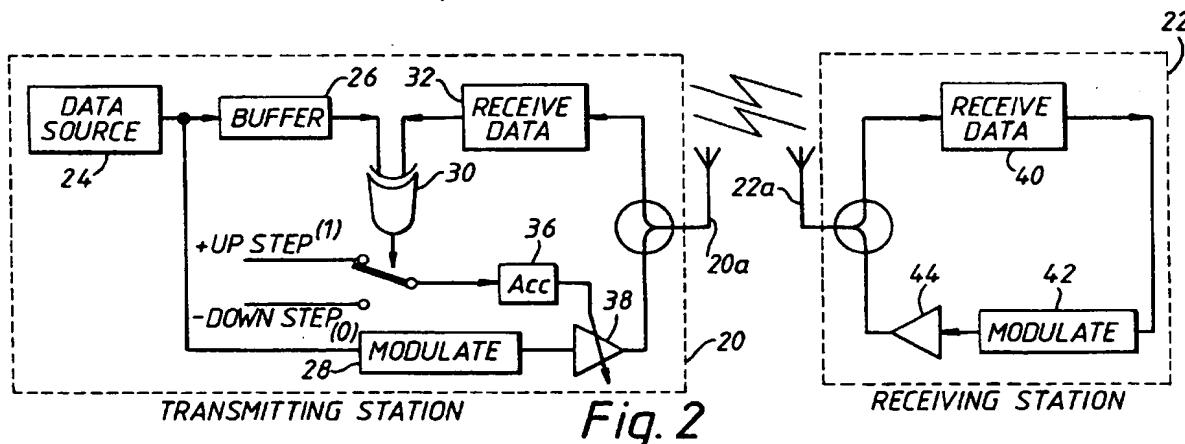
Description

The present invention relates to power control apparatus for use in mobile radio systems.

Known apparatus for providing closed loop control of transmitted RF power, particularly in the context of CDMA Cellular Mobile Radio, include a means of measuring the received power, a means of comparing the measurement against a threshold, a means of generating a correction signal based on the above comparison, a means of communicating the correction signal from the received station to the transmitting station, and a means of controlling the transmission power at the transmitting station in accordance with the correction signal.

The principle is illustrated in Figure 1. Here the transmit power of the mobile station 2 is controlled by the base station 4. The mobile station 2 transmits at the current power level via a combiner/splitter and antenna 2a and has an oscillator 16 and a transmit amplifier 18. The signal is received at the base station 4 and the power is measured (the diode 6 represents a more complex power measurement operation). The power is then compared against a threshold by a comparator 8. When the power exceeds the threshold a 'down' signal is generated. When the power is less than the threshold, an 'up' signal is generated. These are transmitted back to the mobile station via a modulator 10, via a combiner/splitter and antenna 4a, over the other half of the duplex channel and received in the mobile station which demodulates the signal in the demodulator 12 and accumulates them (+1 for an up signal, -1 for a down signal), in the accumulator 14. The output of the accumulator 14 controls the amplifier 18 and hence, the power directly according to a logarithmic relationship.

A vital element in the above procedure is the measurement of received signal level. The control of power can only be as accurate as this measurement. This is not a problem for existing systems in which the power control update interval corresponds to several received bits of data and in which the required bit error rate is moderately low and therefore the received signal to noise ratio is moderately high. The ability to average the received power over several bits of signal gives a significant increase in signal to noise ratio, particularly if this can be done coherently or pseudo coherently.

However, consider the case where the bit rate is very low. In fact, consider the case where the transmitted bit rate is equal to the power control update rate and where the required error rate is moderately high. If a measurement of the received power is made in the receiving station this can only be performed on the basis of a single bit. The signal to noise ratio is perhaps as low as 0 dB on that bit so measurements will be heavily corrupted by noise.

This situation can arise, unlike that illustrated in Figure 1, in the situation where rapid downlink power control is required so that the mobile must transmit power control signalling information to the base station. The transmission of this power control signalling information must itself be power controlled. For transmission of packet type data, it may be a requirement to permit asymmetrical traffic flow so that, on occasions, data traffic will be flowing only on the downlink. In this case the sole purpose of uplink transmissions is for power control of the downlink and these power control transmissions at the power control signalling rate must themselves be power controlled.

The particular difficulty of this situation is the fact that, when there is no uplink data traffic on a particular link, the interference generated by any control traffic flowing on that uplink should be minimised in order to maximise the total capacity available to other links which are active on their uplinks. If power control traffic is, in fact, the only control traffic on an uplink then the transmission used to send it must be minimised, exploiting as much as possible, the very low bit rate. This can only be achieved effectively by exerting fast power control over the power control information transmission.

An aim of the present invention is to provide a power control apparatus for use in mobile radio systems wherein power control is exerted in a fast and efficient manner.

According to the present invention there is provided power controller apparatus for use in mobile radio systems comprising a first station for transmitting data to and receiving data from a second station, a second station for receiving data from and transmitting data to said first station, said first station comprising a data source, means for modulating the data source and means for transmitting data derived from said data source, and control means for controlling the power of the transmitting means in dependence upon data which is being transmitted from said first station to said second station, and then re-transmitted back to said first station.

An embodiment of the present invention will now be described with reference to Figure 2, which is a block diagram of power control apparatus.

Referring to Figure 2, there is shown a transmitting station 20 and a receiving station 22. The transmitting station includes a data source 24 connected to a buffer store 26, and to an input of a modulation circuit 28. The output of the buffer store 26 is connected to a first input of an exclusive OR-gate 30, which at a second input thereof, receives incoming data from the receiving station via the received data circuit 32. The output of the exclusive OR-gate 30 controls a switch 34, which applies an up-step signal or a down-step signal to the input of an accumulator 36. An output from the accumulator 36 is connected to control a transmit amplifier 38.

The receiving station 22 includes a received data circuit 40 which is connected to an input of a modulation circuit 42, the output of which is connected to a transmit amplifier 44.

To avoid confusion in the following discussion, the station whose transmit power is being controlled by the invention described herein is referred to as the 'transmitting station', (first station), whilst the station which is receiving the power controlled transmission and provid-

ing information relevant to the control of the transmitting station's power is referred to as the 'receiving station' (second station). This terminology does not imply that the transmitting station cannot receive, nor that the receiving station cannot transmit.

The basic principle is to have the receiving station 22, rather than measuring the power, simply demodulate the data and communicate this data back to the transmitting station 20, over the link operating in the other direction. It is assumed that the opposite direction link can be made more effectively (i.e. with lower errors) than the power controlled direction.

In the transmitting station 20, the bit which was transmitted is compared against the bit reflected back from the receiving station in order to identify those bits which were received in error at the receiving station. Whenever an error is detected, the transmitted power is increased by an amount U dB. Whenever an error is not detected, the transmitted power is decreased by an amount D dB.

In the steady state the medium term average transmitted power is constant. Consider an interval of time consisting of N signalling bits. Suppose the bit error rate was B. Then the average number of up-steps over interval N is N.B and the total power rise associated with the errors was U.N.B. This must have been cancelled by an equal power reduction. The power reduction is also given by

$$N.D(1-B)$$

because N(1 - B) is the average number of steps in which there were no errors. Thus

$$N.D(1-B)=U.N.B$$

Solving for B we find that

$$B = \frac{U}{U+D}$$

Thus, we can control the bit error rate directly, simply by setting the ratio of U to D.

The optimum step size, U, is a function of the fading rate of the path. For slowly fading paths, U (and therefore D) should be made quite small. For rapidly fading paths, U should be made larger. The step size could be adapted according to measurements of the statistics of bit errors in the transmitting station.

For some systems, this 'reflecting back' of data also permits a further advantage. For a low bit rate link it is usually not possible to achieve coherent demodulation because of the phase ambiguity which can arise in any decision direction derivation of a carrier reference. However, if the data is reflected back, then the transmitting end can detect a burst of errors (as opposed to erasures)

at the receiving end which implies that the carrier reference has become inverted. In this case the transmitting end simply inverts its transmission in order to compensate for the receiver inversion of data 'at source'.

The apparatus shown in Figure 2 operates as follows. The transmitting station 2a modulates the data from the data source 24 via the modulation circuit 28 onto the transmitter at the current power level via a combiner/splitter and antenna 20a. This is received at the receiving station, modulated back onto its transmitter and sent back to the receiver in the transmitting station 22 by way of the transmitter amplifier 44 and combiner/splitter and antenna 22a. The two directions of communications would generally be differentiated by frequency, however, because of the delay around the modulation, propagation and demodulation paths in both directions, the data source is buffered by buffer store 26 before comparison against the reflected data. The exclusive OR-gate 30 performs the comparison. If the bits are equal its output will be low (0) and the accumulator 36 input will be fed with '- Down Step'. If the bits are different betokening an error then the output will be high (1) and the accumulator input will be fed with '+ Up Step'. The output of the accumulator controls the power of the transmitter 38 in a logarithmic fashion.

It will readily be appreciated by those skilled in the art that various modifications are possible within the scope of the present invention.

Claims

1. Power controller apparatus for use in mobile radio systems comprising a first station for transmitting data to and receiving data from a second station, a second station for receiving data from and transmitting data to said first station, said first station comprising a data source, means for modulating the data source and means for transmitting data derived from said data source, and control means for controlling the power of the transmitting means in dependence upon data which is being transmitted from said first station to said second station, and then re-transmitted back to said first station.

2. Apparatus as claimed in claim 1, wherein the control means comprises an exclusive OR-gate arranged to receive the data from said data source at a first input thereof, and at a second input thereof arranged to receive the data returned from said second station, and in accordance with the comparison therewith, generates an output signal for controlling switching means arranged to control an input signal to an accumulator the output of which is used to control the transmitting means in logarithmic fashion.

3. Apparatus as claimed in claim 2, wherein when the exclusive OR-gate performs the comparison, if the input bits at each of its inputs are equal, then the output will be low and the accumulator will be fed

with a down-step signal, and if the input bits are different, indicating an error, the output of the OR-gate will be high and the accumulator input will be fed with an up-step signal.

4. Apparatus as claimed in any preceding claim, wherein the second station includes means for receiving data, means for modulating the data, and means for transmitting the data back to the first station.

5. Apparatus as claimed in any preceding claim, wherein said first station is arranged to detect a burst of errors in data reflected back from said second station, indicating that a carrier reference has become inverted, and said first station includes means arranged to invert data if it is transmitting to compensate for the burst of errors.

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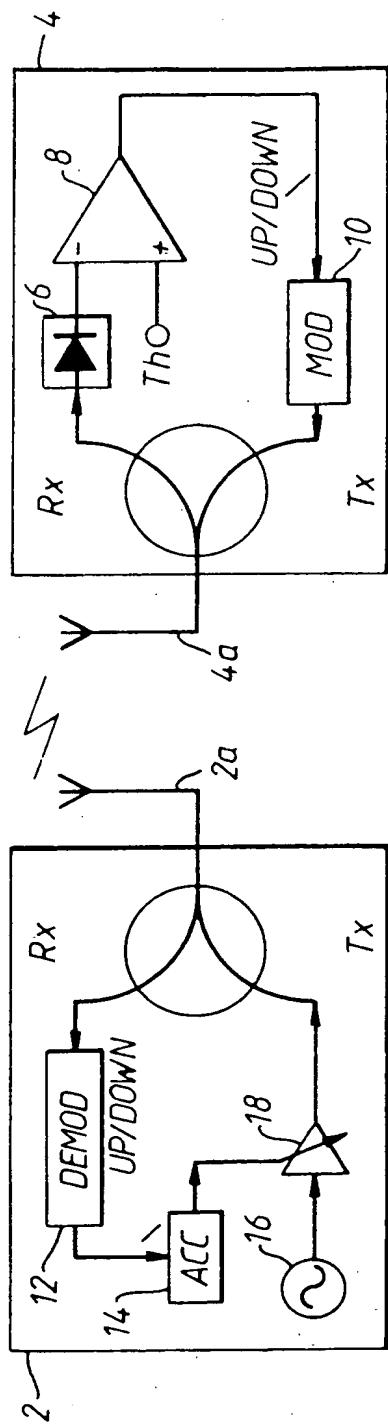
Fig.1
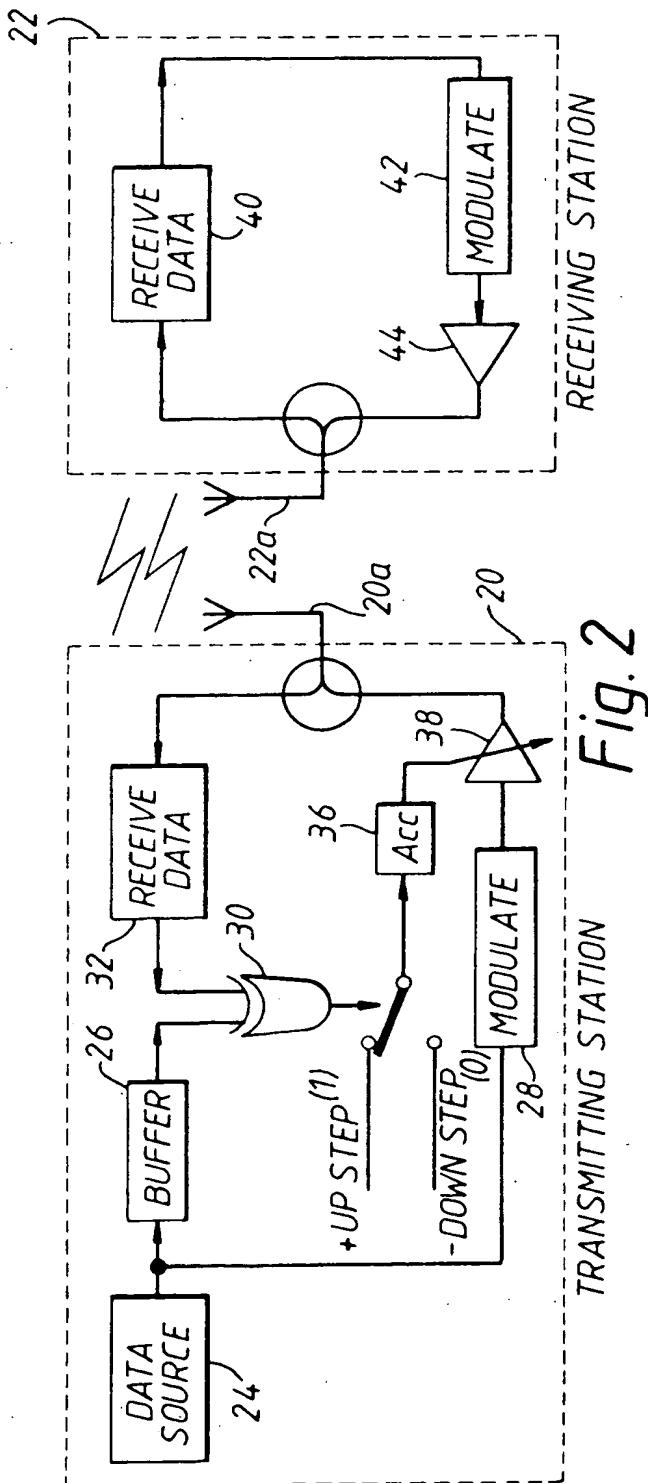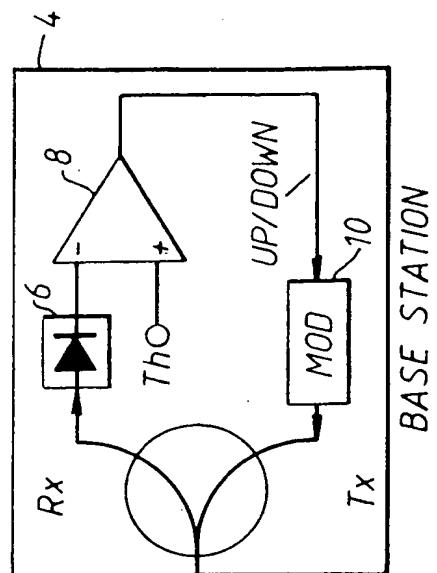
Fig.2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 95 10 9874

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	VEHICULAR TECHNOLOGY SOCIETY 42ND VTS CONFERENCE - FRONTIERS OF TECHNOLOGY, vol. 2 OF 2, 10 May 1992 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 989-992, RIAZ ESMAILZADEH ET AL 'POWER CONTROL IN PACKET SWITCHED TIME DIVISION DUPLEX DIRECT SEQUENCE SPREAD SPECTRUM COMMUNICATIONS'	1,4,5	H04B7/005
Y	* page 989, right column, line 3 - line 8 * * page 989, right column, line 30 - line 38 * * page 991, left column, line 5 - line 19 * ---	2,3	
Y	PATENT ABSTRACTS OF JAPAN vol. 017 no. 614 (P-1642) ,11 November 1993 & JP-A-05 189329 (NEC CORP) 30 July 1993, * abstract * ---	2,3	
X	PROCEEDINGS OF THE NATIONAL COMMUNICATIONS FORUM, vol. 41, no. II, 1987 CHICAGO, ILLINOIS, USA, pages 957-961, W.A. CONNER 'AUTOMATIC POWER CONTROL IN MICROWAVE COMMUNICATIONS' * page 958, right column, line 1 - line 23 * ---	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04B
A	US-A-4 228 538 (SCHARLA-NIELSEN HANS ET AL) 14 October 1980 * column 2, line 15 - line 55 * * column 6, line 16 - line 36 * * column 10, line 16 - line 38 * -----	1-5	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 December 1995	Canali, F

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